APPLICATION FOR
UNITED STATES PATENT
IN THE NAME OF

CORY COX
PHILIP LANTZ

Assigned to

INTEL CORPORATION

for

CALIBRATION SYSTEM FOR VISION-BASED AUTOMATIC WRITING IMPLEMENT

Prepared by:

Pillsbury Winthrop LLP
725 South Figueroa Street, Suite 2800
Los Angeles, California 90017-5406
Tel: (213) 488-7100
Fax: (213) 629-1033

ATTORNEY DOCKET NO. 081674-0275027

Express Mail No. EL 724 020 012 US

CALIBRATION SYSTEM FOR VISION-BASED AUTOMATIC WRITING IMPLEMENT

BACKGROUND

1. Field of the Invention

Embodiments described herein are directed to an automatically controlled writing implement with a digital camera, which draws or writes on a substrate and recognizes what a user draws or writes on that same substrate.

2. Related Art

Both interactive systems and non-interactive systems that use controllers to recognize a target are known in the art. For example, U.S. Patent No. 5,901,978, entitled "Method and Apparatus for Detecting the Presence of a Child Seat," teaches a method and system for detecting the presence of a child seat, more particularly to a method and apparatus for detecting the presence of a child seat in a rear-facing position, on a seat in which information about its contents is obtained and a signal is generated based on any contents of the seat. The analysis of the signal is preferably by pattern recognition techniques that can recognize and thus identify the contents of the seat.

U.S. Patent No. 5,919,045, entitled "Interactive Race Car Simulator System," discloses an interactive vehicle simulator system that receives input signals indicative of the actions of a user who is located in a driver module. The simulator system also displays images and moves the driver module in accordance with the input signals.

U.S. Patent No. 6,026,798, entitled "Professional Batting Training Machine," discloses a baseball pitching machine employing a counter-rotating wheel type baseball launch subsystem that pitches a series of baseballs as well as a computer controlled system for selecting the type and percentage of pitches, pitcher and batter characteristics, strike zone areas, and other parameters to provide a meaningful batting training session.

U.S. Patent No. 6,188,484, entitled "Method and Apparatus for Measuring Angular Displacement of an Actuator Arm Relative to a Reference Position," further teaches an apparatus for measuring directly an angular displacement of an actuator arm relative to a reference position, wherein the actuator is rotatable about a fixed axis.

The above-referenced examples are useful in their particular fields, such as for child safety, recreation, improvement of sports skills, and the like. The technology of recognizing a

target may also be employed in interactive games. Using a digital video camera for the purpose of detecting substrate movement, an automatically controlled pen may draw or write on a substrate and recognize what a user draws or writes on the same substrate. Problems may arise since the user may move the substrate while drawing, thereby confusing the drawing and recognition processes. To alleviate this problem, a controller draws a specialized asymmetrical target on the substrate initially. Before each drawing, the controller uses the camera to find and recognize the target and determine the orientation as well as the position of the substrate. This allows for interactive games such as tic-tac-toe, hangman, and the like to be played.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that all of the structural and functional features for attaining the objects of the Calibration System for Vision-Based Automatic Writing Implement may be readily understood, a detailed description of embodiments of the invention will be made with reference to the accompanying drawings, wherein like numerals designate corresponding parts in the several figures.

FIG. 1 is a flow chart illustrating the steps associated with a system for detecting substrate movement.

FIG. 2a depicts a specialized target in the form of a circle.

FIG. 2b depicts a specialized target in the form of a square.

FIG. 3 depicts a drawing of a specialized target on a blank substrate with the use of an automatically controlled writing implement.

FIG. 4 depicts a digital video camera observing the target drawn on the substrate.

FIG. 5 depicts the drawing on the substrate by the automatically controlled writing implement based on the position and orientation of the substrate.

FIG. 6 depicts a computer interfaced to the base of an articulated robot arm.

DETAILED DESCRIPTION

The following paragraphs describe a calibration system for a vision-based writing implement according to an embodiment of the present invention. According to one embodiment of the present invention, as illustrated in FIG. 3, an articulated robot arm **320**, secured to a base **325**, has software-controlled mechanical actuators and sensors **335** and a digital video camera **330** appended to it. The digital video camera **330** may also be mounted in some other way, such as on a tower mounted to the base **325** of the articulated robot arm **320**. An automatically

controlled writing implement **315** draws or writes on a substrate **310.** The substrate **310** may be a sheet of paper, a blackboard, a whiteboard, or the like. Through the use of the digital video camera **330**, the system recognizes what a user draws or writes on the same substrate **310**. It is assumed that the substrate **310** does not move while the automatic writing implement **315** is drawing. The user, of course, may move the substrate **310** while drawing or writing, thereby confusing the drawing and recognition processes.

FIG. 1, together with FIG. 3, illustrates the overall operation of a calibration system for a vision-based automatic writing implement according to an embodiment of the present invention. As an example, the system may engage in an interactive game of tic-tac-toe with a user. The game may be pre-loaded into the system through an applicable CD ROM disk drive or floppy disk drive **340**. The game may further be built into the system. Moreover, the game may be located on a separate computer **610**, as shown in FIG. 6. In such a case, the articulated robot arm **320** would provide sensor data to the computer **610** and the game itself would run on the computer **610**.

The user places a blank substrate **310** in proximity to the articulated robot arm **320**. A base **325** supports the articulated robot arm **320**. The articulated robot arm **320** is capable of picking up and holding small objects, namely an automatically controlled writing implement **315**. The writing implement **315** may be a pen, pencil, marker, crayon, piece of chalk, or the like. The arm **320** is of such a size and type to be suitable for a child of approximately eight years of age. Appended to the articulated robot arm **320**, in this embodiment, is a digital video camera **330**. The digital video camera **330** sends video to the controller of the computer **610**. The computer **610** is connected to the apparatus via an appropriate serial or parallel interface **615**. Wireless connection is also possible. The controller may further be built into the apparatus such as in the articulated robot arm **320** or in the base **325**. Moreover, parts of the controller may be located within the apparatus such as in the articulated robot arm **320** or in the base **325**, and other parts of the controller may be located in a separate computer **610.** The digital video camera **330** is similar in operation to a personal computer camera sold by Intel Corporation such as the Intel® Easy PC Camera, Intel® Deluxe PC Camera, Intel® Pro PC Camera, or Intel® Pocket PC Camera.

The system, using the digital video camera **330**, recognizes that the substrate **310** is blank, as represented by step **110**. The digital video camera **330** acts as an image sensor for the

system. Next, the automatically controlled writing implement **315** is employed by the system to draw a specialized target **210b** on the substrate **310**, as shown in step **115** and illustrated in FIG. 3. FIG. 2a depicts a specialized target **210a** in the form of a circle. FIG. 2b depicts another specialized target **210b** in the form of a square. The specialized target **210** may be of a wide variety of shapes. At this stage, the writing implement **315** may also draw the tic-tac-toe board **410,** as shown in FIG. 4, as well as make the first play by placing either an "X" or an "O" in one of the nine squares. The system observes and remembers the relative positions and orientations of the specialized target **210b** and the drawing, here the tic-tac-toe board **410**.

The user is then allowed to make a move on the game board **410**. While the user is marking the substrate **310**, the digital video camera **330** is placed in such a position to observe the substrate **310**, as illustrated by step **120**. In each video frame, as provided by the digital video camera **330** to the controller of the computer **610**, the system searches for the specialized target **210b**, as shown by step **125**. The result of this search includes both the location of the specialized target **210b** in the video frame and its orientation. That is, the controller uses the digital video camera **330** to find and recognize the specialized target **210b** and to determine whether the substrate **310** has moved, as shown by step **130**. The target **210b** is asymmetrical, thereby allowing for the determination of the orientation and location of the substrate **310**. Software analysis by way of pattern matching occurs in determining whether the substrate **310** has rotated. The controller can then orient its drawing and any recognition algorithms to the new location and orientation of the substrate **310**, if the substrate **310** has indeed moved. The necessary software may be loaded into the apparatus itself. It may further be installed on the computer **610** and downloaded.

If the system finds the specialized target **210b**, it then locates the drawing, here the tic-tac-toe board **410**, in the video frame relative to the specialized target **210b**, as illustrated in step **135**. By examining the tic-tac-toe board **410** in the video frame, the system determines whether the user marked the substrate **310**, as represented by step **140**. The system repeats steps **125**, **130**, **135**, and **140** until the system determines that the user has marked the substrate **310**, i.e. made a move on the tic-tac-toe board **410**.

At this time, the interactive system proceeds to make its own move, using the position of the specialized target **210b** to find the location of the substrate **310** where it should draw. This process is shown as step **145**. The calibrations system then determines whether the game is

completed, as illustrated in step **150**. If the game has not reached completion, the system returns to step **120** of allowing the user to make another marking on the substrate **310**. The entire process continues until the game is completed. If the game has reached completion, the system returns to step **110**. The same process would take place for any other kind of interaction that the system might perform. As suggested above, hangman is another viable option whereby the system would draw the blanks, and the user would fill in the blanks with letters of the alphabet. The system, which is pre-programmed with the final pattern, would also draw an limb of a person's body each time that the user incorrectly placed a letter in a blank. It should be appreciated that tic-tac-toe and hangman are not the only interactive games that a user may play with the system. They are named merely for illustrative purposes.

FIG. 5 illustrates the drawing on the substrate **310**, by the automatically controlled writing implement **315** based on the position and orientation of the observed specialized target **210b**. In this drawing configuration, the controller cannot observe the specialized target **210b**. The controller has, however, already determined where it should draw by observing the position of the target **210b**. As illustrated here, the system has already drawn the tic-tac-toe board **410**, made a move by placing an "X" in the middle square, allowed the user to mark the substrate **310**, as represented by the dotted "O", observed the substrate **310**, searched for the specialized target **210b** in a plurality of video frames, determined whether the substrate **310** moved, located the drawing in the video frame relative to the specialized target **210b**, and examined the drawing and determined that the user in fact marked the substrate **310** with an "O." As such, FIG. 5 corresponds to step **145** in FIG. 1, whereby the system makes a subsequent drawing, here the second "X" by using the position of the specialized target **210b** to find the location of the substrate **310** where it should draw.

While the above description refers to particular embodiments of the present invention, it will be understood to those of ordinary skill in the art that modifications may be made without departing from the spirit thereof. The accompanying claims are intended to cover any such modifications as would fall within the true scope and spirit of the present invention.

The presently disclosed embodiments are therefore to be considered in all respects as illustrative and not restrictive; the scope of the invention being indicated by the appended claims, rather than the foregoing description. All changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraces therein.